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Åsa KUTSCHER et al.	)	Group Art Unit: 1774
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Application No.: 08/923,922	)	Examiner: A. Turner
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Filed: September 5, 1997	)	
	)	
For: COATED CUTTING INSERT	)	

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CLAIM FOR CONVENTION PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The benefit of the filing date of the following prior foreign application in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed:

Swedish Patent Application No. 9603264-4,

Filed: Sepember 6, 1996.

In support of this claim, enclosed is a certified copy of said prior foreign application. Said prior foreign application was referred to in the oath or declaration. Acknowledgment of receipt of this certified copy is requested.

Respectfully submitted,

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Avgift
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Coated cutting insert

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for machining of cast iron parts by turning.

Cast iron materials may be divided into two main categories, grey cast iron and nodular cast iron. Typical for cast iron materials is that they often have an outer layer of cast skin, which might contain various inclusions of sand, rust and other impurities, but also a surface zone which is decarburized and contains a larger amount of ferrite than the rest of the material.

The wear when machining grey cast iron materials with Al_2O_3-coated cutting tools is dominated by chemical, abrasive and so called adhesive wear. In order to protect the cutting tool against chemical wear it is desirable to use as thick Al_2O_3-layers as possible. This is contradicted by the properties regarding adhesive wear that this type of layer generally possesses. Adhesive wear occurs when fragments or individual grains of the layer are pulled away from the cutting edge by the work piece chip formed. Especially the surface zone with high amounts of ferrite puts severe demands on the adhesive properties of the coating, and in combination with the inclusions in the cast skin on the work piece this causes notch wear at the depth of cut at the main cutting edge.

Another feature in the machining of grey cast iron is the sensitivity for excessive amounts of Co binder phase in the interface between the cemented carbide cutting insert and the coating. Excessive amounts of Co binder face deteriorates the adhesion between coating and cemented carbide and leads to flaking of the coating during machining.

Swedish patent application 9502640-7 discloses a coated cutting insert tool consisting of a cemented carbide body of a composition 5-11 wt-% Co, <10%, preferably 1.5-7.5 wt-%, cubic carbides of the metals Ti, Ta and/or Nb and balance WC, especially suited for machining of low alloyed steel components by turning.

It has surprisingly been found that by combining the following features: a cemented carbide body with a highly W-alloyed binder phase, a low content of cubic carbides and a well defined surface composition resulting from a specific sintering process, a columnar $TiC_xN_yO_z$-layer, a textured α-Al_2O_3-layer, a TiN-layer, fulfilling the demands of easy identification of used edges, and a post-treatment of the coated cutting edge by brushing, an excellent cutting tool for machining of cast iron materials, especially grey cast iron, can be obtained.

Fig 1 is a micrograph in 2000X magnification of a coated insert according to the present invention in which

A - cemented carbide body
B - $TiC_xN_yO_z$-layer with equiaxed grains
C - $TiC_xN_yO_z$-layer with columnar grains
D - $TiC_xN_yO_z$-layer with equiaxed or needle like grains
E - textured α-Al_2O_3-layer with columnar like grains
F - TiN-layer

According to the present invention a cutting tool insert is provided with a cemented carbide body of a composition 5-8 wt-% Co, <2 wt-%, preferably <0.5 wt-%, most preferably 0 wt-% cubic carbides of the metals Ti, Ta and/or Nb and balance WC. The grain size of the WC is in the range of 1-2.5 µm. The cobalt binder phase is highly alloyed with W. The content of W in the binder phase can be expressed as the

$$\text{CW-ratio} = M_s / (\text{wt-\% Co} \cdot 0.0161),$$

where M_s is the measured saturation magnetization of the cemented carbide body in kA/m and

wt-% Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A low CW-value corresponds to a high W-content in the binder phase.

It has now been found according to the invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.75-0.93, preferably 0.80-0.90. The cemented carbide body may contain small amounts, <1 volume-%, of eta phase (M_6C), without any detrimental effect.

The surface composition of the cemented carbide insert is well defined and the amount of Co on the surface is within -2 wt% to +4 wt% of the nominal content.

The coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably y>x and z<0.1, most preferably y>0.8 and z=0, with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm. In an alternative embodiment the $TiC_xN_yO_z$ layer preferably has the composition z<0.5 and y<0.1, most preferably 0.1<z<0.5 and y=0.

- a layer of $TiC_xN_yO_z$ x+y+z=1, preferably with z=0, x>0.3 and y>0.3, most preferably x>0.5, with a thickness of 4-12 µm, preferably 5-10 µm, most preferably 6-9 µm with columnar grains and with a diameter of <5 µm, preferably <2 µm

- a layer of $TiC_xN_yO_z$, x+y+z=1 with z<0.5, preferably x>y, most preferably x>0.5 and 0.1<z<0.4, with a thickness of 0.1-2 µm and with equiaxed or needle like grains with size <0.5 µm, this layer being the same as or different from the innermost layer

- a layer of textured, fine-grained (with average grain size 0.5-2 µm) α-Al_2O_3-layer with a thickness of 3-8 µm, preferably 3-6 µm.

- an outer layer of $TiC_xN_yO_z$. This $TiC_xN_yO_z$-layer consists of one or more layers with the composition x+y+z=1, z<0.05 preferably y>x. Alternatively, this outer layer consists of a multilayer of TiN/TiC/TiN in one or several sequences and a total thickness of 0.5-3 µm, preferably 1-2 µm. This layer exhibits a grain size <1 µm.

In order to obtain a smooth cutting edge line suitable for machining, the edge of the coated insert is subjected to a brushing treatment giving a surface roughness R_{max}≤0.4 µm over a length of 10 µm according to the method described in Swedish patent application 9402543-4. This treatment removes the top layer of $TiC_xN_yO_z$ along the cutting edge line. It is also within the scope of this invention that the surface might be smoothened by a wet blasting treatment.

Furthermore, as disclosed in Swedish patent 501 527 or Swedish patent application 9304283-6 or 9400089-0, the α-

Al_2O_3-layer has a preferred crystal growth orientation in either the (104)-, (012)- or (110)-direction, preferably in the (012)-direction, as determined by X-ray Diffraction (XRD) measurements. A Texture Coefficient, TC, can be defined as:

$$TC(hkl) = \frac{I(hkl)}{I_o(hkl)}\left\{\frac{1}{n}\sum\frac{I(hkl)}{I_o(hkl)}\right\}^{-1}$$

where

$I(hkl)$ = measured intensity of the (hkl) reflection

$I_o(hkl)$ = standard intensity of the ASTM standard powder pattern diffraction data

n = number of reflections used in the calculation, (hkl) reflections used are: (012), (104), (110), (113), (024), (116)

TC for the set of (012), (104) or (110) crystal planes ought to be larger than 1.3, preferably larger than 1.5.

According to method of the invention a WC-Co-based cemented carbide body having a highly W-alloyed binder phase with a CW-ratio is subjected to a sintering process according to prior art including a cooling step which at least to below 1200 °C is performed in a hydrogen atmosphere of pressure 0.4-0.9 bar as disclosed in Swedish patent application 9602750-3.

The insert is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $y>x$ and $z<0.1$, most preferably $y>0.8$ and $z=0$, with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm. In an alternative embodiment the $TiC_xN_yO_z$ layer preferably has the composition $z<0.5$ and $y<0.1$, most preferably $0.1<z<0.5$ and $y=0$.

- a layer of $TiC_xN_yO_z$ $x+y+z=1$, preferably with $z=0$, $x>0.3$ and $y>0.3$, most preferably $x>0.5$, with a thickness of 4-12 µm, preferably 5-10 µm, with columnar grains and with a diameter of <5 µm, preferably <2 µm, deposited preferably by MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 °C). The exact conditions, however, depend to a certain extent on the design of the equipment used.

- a layer of $TiC_xN_yO_z$, x+y+z=1 with z<0.5, preferably x>y, most preferably x>0.5 and 0.1<z<0.4, with a thickness of 0.1-2 µm and with equiaxed or needle like grains with size <0.5 µm, using known CVD-methods this layer being the same as or different from the innermost layer.

- an intermediate layer of a smooth textured α-Al_2O_3-layer according to Swedish patent 501 527 or Swedish patent applications 9304283-6 or 9400089-0 with a thickness of 3-8 µm, preferably 3-6 µm.

-an outer layer of $TiC_xN_yO_z$, comprising one or several individual layers each with composition x+y+z=1 and z<0.05 preferably y>x. Alternatively, this outer layer consists of a multilayer of TiN/TiC/TiN in one or several sequences. The total coating thickness of these outer layers is 0.5-3.0 µm, preferably 0.5-2.0 µm. The grain size in this outer layers is <1.0 µm.

The edge line of the inserts is smoothened e g by brushing the edges with brushes based on e g SiC as been disclosed in the Swedish patent application 9402543-4.

When a $TiC_xN_yO_z$-layer with z>0 is desired, CO_2 and/or CO are/is added to the reaction gas mixture.

Example 1

A. Cemented carbide cutting tool inserts of style CNMG 120412-KM with the composition 6.0 wt-% Co and balance WC were sintered in a conventional way at 1410°C and cooled down to 1200°C in 0.6 bar H_2 giving inserts with a binder phase highly alloyed with W, corresponding to a CW-ratio of 0.85 and a Co-content on the surface corresponding to 7 wt-% as measured with Energy Dispersive Spectroscopy. After conventional ER-treating the inserts were coated with a 0.5 µm equiaxed $TiC_xN_yO_z$-layer, x=0.1, y=0.9, z=0 and an average grain size of approximately 0.2 µm, followed by a 8.0 µm thick TiC_xN_y-layer x=0.55, y=0.45, with columnar grains with an average grain size of 2.5 µm, by using MTCVD-technique (process temperature 850 °C and CH_3CN as the carbon/nitrogen source). In subsequent process steps during the same coating cycle, a 1 µm thick layer of $TiC_xN_yO_z$ (about x=0.6, y=0.2 and z=0.2) with equiaxed grains and an average

grain size of 0.2 µm was deposited followed by a 5.0 µm thick layer of (012)-textured α-Al_2O_3, with average grain size about 1.2 µm, deposited according to conditions given in Swedish patent 501 527. On top of the α-Al_2O_3-layer was TiN/TiC/TiN/TiC/TiN deposited in a multilayer structure with a total coating thickness of 1.5 µm, the average grain size <0.3 µm in each individual layer. Prior to machining the inserts were subjected to a brushing treatment in which the cutting edge lines were smoothened with a 320 mesh brush containing SiC as grinding material, the outer TiN/TiC-multilayer was removed by the brushing treatment along the cutting edge line.

B. Cemented carbide cutting tool inserts of style CNMG 120412-KM with the composition 6.0 wt-% Co and balance WC were coated under the procedure given in A). The cemented carbide body had a CW-ratio of 0.98 and they were subjected to a conventional sintering without H_2 during the cooling step. The Co content on the insert surface was approximately 30 wt-% as measured with Energy Dispersive Spectroscopy. The inserts were subjected to the same brushing treatment as in A.) prior to machining.

C. Cemented carbide cutting tool inserts of style CNMG120412-KM from the same batch as in A.) were coated with a 4 µm equiaxed layer, the grain size was < 2.0 µm, of TiC followed by a 6 µm thick layer of Al_2O_3 according to prior art technique. XRD-analysis showed that the Al_2O_3-layer consisted of a mixture of α and κ-Al_2O_3, approximately in the ratio 60/40, the α-Al_2O_3 showed no preferred growth orientation as measured by XRD. The grain size of the κ-Al_2O_3 was 2.0 µm while the α-Al_2O_3 exhibited grains up to 5.5 µm.

D. Cemented carbide cutting tool inserts from the same batch as in C. The inserts have been subjected to a wet blasting treatment after coating.

E. Cemented carbide cutting tool inserts of style CNMG120412-KM from the same batch as in A.) were coated with a 2 µm equiaxed layer of $TiC_xN_yO_z$, the average grain size of this layer was 0.2 µm, followed by a 8 µm thick columnar TiCN deposited according to prior art technique the grain size in this coating was approximately 3.0 µm and a 6 µm thick layer of

(012)-textured α-Al_2O_3 deposited according to the same process conditions as in A.). The inserts were subjected to the same brushing treatment as in A.)prior to machining.

F. Cemented carbide cutting tool inserts of style CNMG120412-KM with the composition 6 wt-% Co, 4 wt-% cubic carbides and balance WC were subjected to the same coating process as in A.) The CW-ratio of the inserts were 0.88 and they were subjected to a sintering process using H_2 during the cooling step, the Co content on the surface was 9% as measured by Energy Dispersive Spectroscopy. The inserts were subjected to the same brushing treatment as in A.) prior to machining.

The inserts were tested in a facing operation. The work piece material was nodular cast iron, SS717. The workpiece shape causes intermittent cutting conditions during each revolution. Cutting speed is 250 m/min, feed 0.10 mm/rev and cutting depth is 2.0 mm. The operation is performed using coolant.

This type of operation typically causes severe flaking of the coating. The coating is torn off the insert in fragments. The wear can be measured as the part of the edge line on which the coating has flaked off compared to the total length of the edge line used in the cutting operation.

Insert type	% of edge line with flaking
A	<5
B	40
C	100
D	70
E	25
F	20

Example 2.

Inserts of type A, D and E in Example 1 above were tested in an intermittent cutting operation in grey cast iron, SS0125. The cutting conditions put high demands on the flaking resistance of the coating as well as the chemical and abrasive wear resistance of the coating. The shaping of the work piece is such that for each revolution two entrances in the work piece

will be made giving intermittent cutting conditions. The cutting speed v=300 m/min, the cutting feed =0.25 mm/rev and the cutting depth = 2.0 mm. The machining was made without using any coolant.

Insert type	number of passes before the edge was worn out
A	60
D	48
E	48

Example 3.

The same cutting conditions as in example 2 and inserts of type A, C, D, and F from the same batches as in example 1. In this test coolant was used during machining.

Insert type	number of passes	state of the edge
A	60	undamaged edge line, not worn out
C	48	fracture in cutting edge, insert worn out
D	24	fracture in cutting edge, insert worn out
F	24	fracture in cutting edge, insert worn out

Example 4.

Cemented carbide inserts of type A and B in example 1 above were tested in a turning test that causes deformation of the cutting edge leading to flaking of the coating and enhanced wear of the insert. The test is performed in a nodular cast iron SS0737 and for a certain combination of feed and cutting depth in a longitudinal turning operation the highest possible cutting rate before deformation of the cemented carbide occurs is sought.

Insert type	Highest possible cutting speed
A	475 m/min
B	400 m/min

Claims

1. A cutting tool insert comprising a coating and a cemented carbide body c h a r a c t e r i z e d in that said cemented carbide body consists of WC, 5-8 wt-% Co and <0.5 wt%, cubic carbides of metals from groups IVb, Vb or VIb of the periodic table with a highly W-alloyed binder phase with a CW-ratio of 0.8-0.9 and a surface composition of the cemented carbide body being well defined the amount of Co on the surface being within -2 wt% to +4 wt% of the nominal Co-content and in that said coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1 and y>x and z<0.1 with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm

- a layer of $TiC_xN_yO_z$ where x+y+z=1 and z=0, x>0.3 and y>0.3, with a thickness of 5-10 µm with columnar grains with a diameter of <2 µm

- a layer of $TiC_xN_yC_z$ where x+y+z=1, z<0.5 and x>y with a thickness of 0.1-2 µm and with equiaxed or needle like grains with size <0.5 µm

- a layer of smooth, textured, fine-grained (0.5-2 µm) α-Al_2O_3-layer with a thickness of 3-6 µm

- an outer layer of $TiC_xN_yO_z$ x+y+z=1, z<0.05 with a thickness of 0.5-3 µm and a grain size <1 µm

and in that the outer coating layer has been removed in at least the edge line so that the Al_2O_3-layer is on top along the cutting edge line and the outer layer of $TiC_xN_yO_z$ is the top layer on the clearance side.

2. Cutting insert according to the preceding claim c h a r a c t e r i z e d in that the α-Al_2O_3-layer has a texture in (012)-direction and with a texture coefficient TC(012) larger than 1.3.

3. Cutting insert according to any of the preceding claims c h a r a c t e r i s e d in that the first (innermost) layer of $TiC_xN_yO_z$ has the composition z<0.5 and y<0.1.

4. Cutting insert according to any of the preceding claims c h a r a c t e r i s e d in that the outer $TiC_xN_yO_z$ layer consists of a multilayer of TiN/TiC/TiN in one or several sequences.

5. Method of making a cutting insert comprising a cemented carbide body and a coating characterized in that a WC-Co-based cemented carbide body is

- subjected to a sintering process including a cooling step which at least to below 1200 °C is performed in a hydrogen atmosphere of pressure 0.4-0.9 bar and thereafter coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 µm, with equiaxed grains with size <0.5 µm using known CVD-methods

- a layer of $TiC_xN_yO_z$ with a thickness of 4-12 µm with columnar grains and with a diameter of <5 µm deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850-900 °C.

- a layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 µm with equiaxed or needle like grains with size <0.5 µm, using known CVD-methods

- a layer of a smooth textured α-Al_2O_3-layer textured in the direction (012), (104) or (110) with a thickness of 3-8 µm using known CVD-methods

- an outer layer of $TiC_xN_yO_z$ with a thickness of 0.5-3 µm, using known CVD-methods and furthermore

- the outer layer of $TiC_xN_yO_z$ is removed by brushing or blasting in at least the cutting edge line so that the Al_2O_3-layer is on top along the cutting edge line and the outer layer of $TiC_xN_yO_z$ is the top layer on the clearance side of the cutting insert.

Abstract

The present invention discloses a coated cutting insert particularly useful for cutting in cast iron materials. The insert is characterised by a straight WC-Co cemented carbide body having a highly W-alloyed Co-binder phase, a well defined surface content of Co and a coating including an innermost layer of $TiC_xN_yO_z$ with columnar grains, a layer of a fine grained, textured α-Al_2O_3-layer and a top layer of $TiC_xN_yO_z$ that has been removed along the cutting edge line.

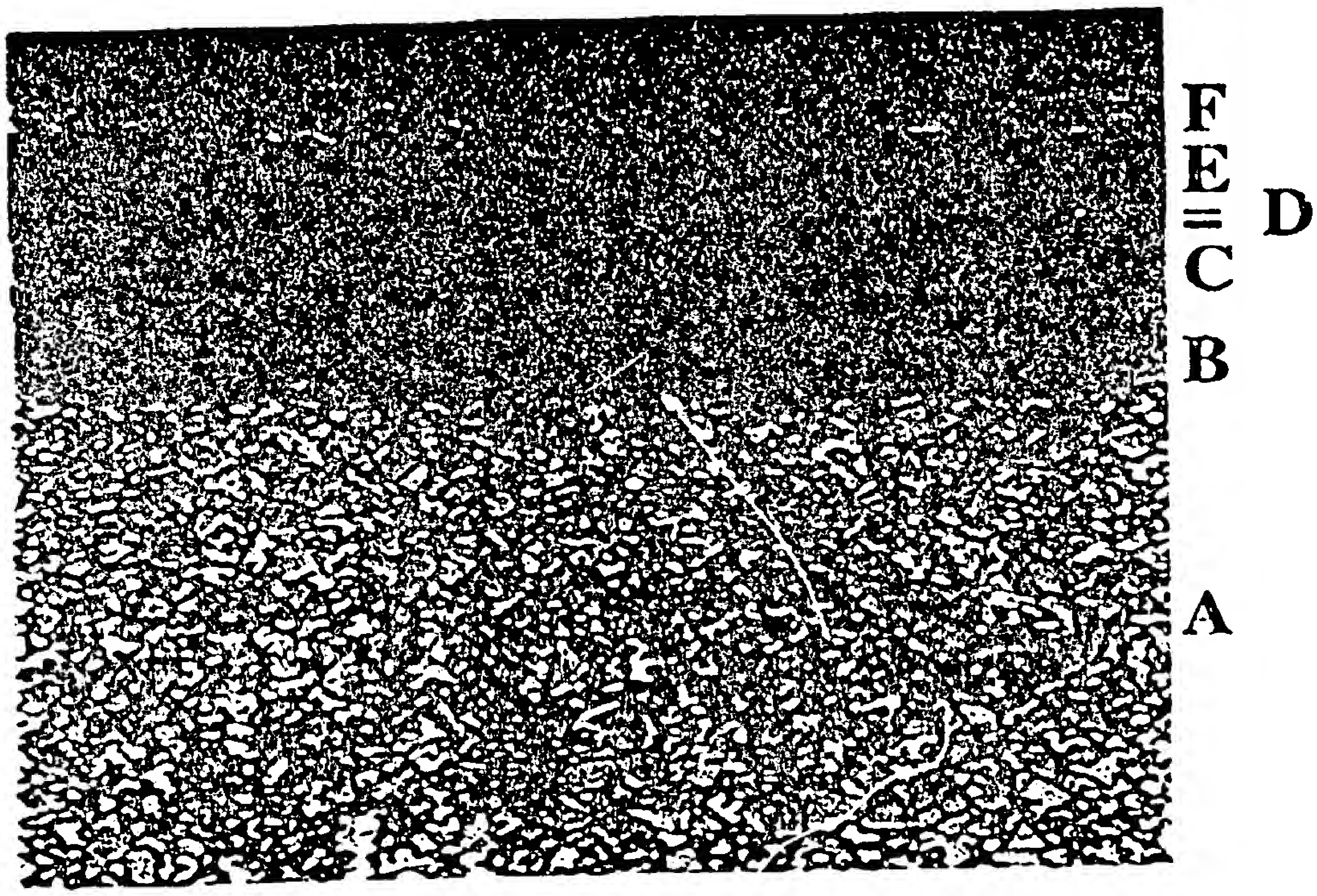

Fig. 1